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LOW LEVEL ALUM ADDITION TO THE SECONDARY SEWAGE TREATMENT PLANT PROCESS

THE ONTARIO WATER RESOURCES COMMISSION

LOW LEVEL ALUM ADDITION

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SECONDARY SEWAGE TREATMENT PLANT PROCESS

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SUMMARY

The addition of small concentrations of alum to one of the four aeration tanks of the Brampton - Chinguacousy sewage treatment plant decreased 5 day biochemical oxygen demand, suspended solids, turbidity and to a limited extent the phosphate in the effluent from the final clarifier.

The most effective quantity of alum addition may be self-limiting in that optimum removals were reached at application of 11 ppm. Brief (several days) application of alum up to 73 ppm did not demonstrate a further improvement in the effluent.

No effect on effluent alkalinity was observed at any of the loadings tested. However, alum added directly to the clarifier tank rather than to the preceding aeration tank caused sludge bulking and a deterioration of effluent quality.

Improved sludge settling characteristics enhanced removal of suspended solids, turbidity and biochemical oxygen demand. Phosphate removals appeared to be a result of direct chemical precipitation.

The study concluded that one pound of alum could remove:

0.92 pounds of BOD

0.97 pounds of suspended solids

and 0.213 pounds of phosphate

Assuming a chemical cost of $70.00 per ton of alum, the removal of additional BOD from a secondary sewage treatment plant effluent through the use of supplemental alum would cost 3.5¢ per pound of BOD removed (chemical cost only). At a limiting concentration of 11 ppm added alum the increase in treatment cost would be $3.90 per million gallons for chemicals only.

INTRODUCTION

The investigation into the possible advantages of adding small amounts of inorganic coagulants to the biological treatment process was in part stimulated by observations made during a series of jar tests studying the removal of effluent phosphates using inorganic coagulants. It was observed that relatively small quantities of coagulants such as aluminum sulphate, ferric chloride and activated fly ash appeared capable of lowering the BOD content of a sewage treatment plant effluent even when the amount of coagulant was of insignificant quantity to affect the phosphate content. As low as 40 parts per million (ppm) alum was found to remove as much as 65% of the BOD remaining in the effluent.

This observation was compared with earlier findings (2) (3) on the Guggenheim Biochemical Process where a coagulant such as ferric chloride was used to produce distinct advantages when added to the biological floc. A more recent paper by Tenney and Stumm (4) had suggested that to assist sludge flocculation, alum additions had to exceed the requirements of complete phosphate precipitation before sludge settling improvements could be observed. However, the concentration

range where insignificant phosphate removal would be expected had not been generally studied although this concentration might prove of value judging by the observations noted in the phosphate removal studies.

Addition of alum to the Brampton plant was feasible way of testing the possibilities. The Brampton - Chinguacousy plant was well suited for the study as its treatment system had two closely matched treatment lines operating in parallel. One treatment line of the plant could serve as a control in the study.

THE BRAMPTON - CHINGUACOUSY SEWAGE TREATMENT PLANT

Designed for 2 MGD, this plant treated sewage flows ranging from 1.3 to 2.9 MGD. The flow was divided relatively evenly into two primary settling tanks whose effluents in turn were divided into two aeration tanks each. All four aeration tanks provided roughly equivalent treatment and passed their effluents into four final clarifiers whose effluents were mixed prior to passage through the chlorine contact chamber.

For the purpose of this study, the most easterly clarifier was identified as "Clarifier #1" and it was this clarifier and the aeration tank preceding it that received the alum solution feed. "Clarifier #2" was the second clarifier from the east side. It would be indirectly influenced by the alum as a result of a common sludge recirculation line with Clarifier #1. The remaining two clarifiers on the west side of the plant were grouped together as "Clarifier #3". The west side of the plant had a separate sludge system.

Equipment-Layout and Operation

A 240 gallon tank was located on the roof of the plant building. Seventeen feet below, at the base of the building, was situated a 500 gallon tank. The upper tank was used to make up concentrated alum solution. Six bags of alum (600 pounds) were charged into approximately 150 gallons of water and dissolved by overnight stirring using the portable mixer to give about 190 gallons of solution containing 40% alum.

Varying concentrations of alum solutions were made up in the tank below. The lower tank served as the feed tank for dosing out alum solution. Concentrate solution was passed down to it through a gravity feed line from the elevated tank.

A floating weir system was initially employed in the 500 gallon feed tank to regulate the alum solution discharged to the sewage treatment process. On January 1 a "Lapp Pulsator" liquid feeder was installed, replacing the weir system.

Test Procedure

The study consisted of adding alum feed solution to either Clarifier #1 or to the aeration tank discharging to Clarifier #1. Direct addition to the clarifier inlet was studied commencing October 27, 1966, and this aspect of the investigation was terminated on November 8, 1966, as indications of increased sludge volume showed no sign of mitigating. Thereafter, alum additions were restricted to aeration tank #1.

Alum solution additions to the treatment process were generally maintained at an even rate to build up a statistically significant body of reportable evidence. No attempt was made, however, to smooth out minor fluctuations in the alum addition, as it was felt that such fluctuations would have considerable value in interpreting the effect of the chemical.

When the heavy duty liquid feeder was installed to replace the floating weir, a number of tests were made using much increased concentrations of alum feed. Lack of significant response to heavier dosages (up to 73 ppm alum) and the difficulty of maintaining high feed rates suggested that a minimum effective alum requirement would be a most

practical determination. Alum feed rates were then lowered to an average 5 parts per million and maintained there to accumulate further statistical data for comparison.

In addition to maintaining the alum feed, daily sampling of the treatment plant was required. Grab samples were taken of the effluents from Clarifiers #1, #2 and #3. Grab samples were also taken of the separate sludge return lines, one on the east side of the plant and one on the west side of the plant. Samples were taken at a standard time of the day, but no essential differences in sample characteristics were noted when the time of sample collection was altered.

Clarifier samples were routinely submitted for analysis of 5 day BOD, suspended solids, pH, alkalinity, total Kjeldahl nitrogen, total phosphate and turbidity. Periodically clarifier effluents were also analyzed for aluminum and ignited solids. Samples of the return sludge were submitted for analyses determining suspended solids, ignited solids, pH, total Kjeldahl nitrogen, total phosphate and total aluminum. Some sludge samples were also analyzed for alkalinity. The analytical procedures followed were those given in "Standard Methods for the Examination of Water and Wastewater" (5).

Data Evaluation

The analytical results of submitted samples were combined with 24 hour waste flow readings to tabulate the quantities of daily contaminants concurrent with the known alum additions. Statistical comparisons of contaminant concentrations and quantities with alum feed were determined and summarized. The influence of the weather was taken into consideration.

Results

The addition of alum to the secondary sewage treatment process produced significant changes in the analytical variables maintained under observation. The effects of the added alum upon effluent BOD, suspended solids, turbidity, total phosphate, alkalinity and Kjeldahl nitrogen were deemed most important in the study.

(a) The Effect on Effluent BOD

There was an obvious difference observed between the effect of adding alum solution directly to the final clarifier inlet and that of adding it to the aeration tank preceding the clarifier. When alum was added directly to

Clarifier #1, both Clarifiers #1 and #2 showed conditions of worsened sludge settling relative to the control clarifiers as represented by Clarifier #3. This direct feed period from October 27 to November 8, 1965, showed sludge bulking associated not only with higher BOD, but also with higher suspended solids and turbidity in the effluent supernatant.

Alum additions directly to the aeration tank had an apparent beneficial effect in lowering effluent BOD in the clarifier effluents. The effect is apparent in the experimental data by comparing the results of two periods from November 9 to December 10, 1965 and February 7 to March 5, 1966. Results were as shown in Table 1.

TABLE 1

Alum Effect on BOD — Period: Nov.9 to Dec.10, 1965 / Feb.7 to Mar.5, 1966; Volume: 17.9 Million Gal./clarifier / 16.5 Million Gal./clarifier

Alum Effect on BOD	Clarifiers 1 (Nov.9 to Dec.10, 1965; 17.9 Million Gal./clarifier)	2	3	Clarifiers 1 (Feb.7 to Mar.5, 1966; 16.5 Million Gal./clarifier)	2	3
Added Alum conc.-ppm						
(i) Simple average	11.25	recirc.	-	5.41	recirc.	-
(ii) Weighted average	10.98	recirc.	-	5.56	recirc.	-
Effluent BOD conc.-ppm						
(i) Simple average	25.3	30.5	38.8	16.4	16.2	14.6
(ii) Weighted average	25.6	30.0	39.7	16.5	15.6	15.2
Total Alum added-pounds	1970	recirc.	0	1091	recirc.	0
Total BOD in effluent - pounds	4583	5370	7109	2730	2581	2509
Improved Removal pounds BOD	2526	1739	0	-221	-72	0

This comparison would indicate that the additional 879 pounds (from 5 ppm to 11 ppm) of alum resulted in the removal of 2747 pounds of BOD from the effluent of Clarifier #1 and that 1811 pounds of the BOD removal resulted from the recycle of alum bearing sludge as demonstrated in Clarifier #2. Inherent in these observations is evidence that without any alum additions, Clarifier #3 would out perform Clarifier #2, which would in turn out perform Clarifier #1 in terms of BOD removal. The operators at the Brampton plant confirmed this finding.

One other observation of note is the fact that greatly increased alum additions (up to 73 parts per million) did not appreciably improve the effluent further than the values observed for the 11 ppm addition averaged for the November 9 to December 10, 1965 period.

(b) The Effect on Suspended Solids

In close similarity to the effect of alum addition on effluent BOD, the introduction of alum into the treatment process affected significant changes in the suspended solids content of clarifier effluents. When the alum solution was being added directly to the inlet mixed liquor flow to

Clarifier #1, sludge bulking was encountered in both Clarifiers #1 and #2. The effect on the clarifiers was visually observable and the increased suspended solids in the effluent were associated with higher BOD's and turbidities.

When the alum feed was redirected into the aeration tank supplying Clarifier #1, a reduction in effluent suspended solids was noted for both Clarifiers #1 and #2. The effect was much greater for Clarifier #1 receiving the fresh as well as recycled coagulant through its aeration tank. The rate of sludge settling however was not appreciably affected below 20 ppm alum addition. The general effect on suspended solids is shown for the two periods of sustained alum additions in Table 2.

TABLE 2

Alum Effect on Susp. Solids	Period: Volume:	Nov.9 to Dec.10, 1965 17.9 Million G. per Clarifier			Feb.7 to Mar.5, 1966 16.5 Million G. per Clarifier		
		Clarifiers			Clarifiers		
		1	2	3	1	2	3
Added Alum conc.-ppm							
(i) Simple average		11.25	recirc.	-	5.41	recirc.	-
(ii) Weighted average		10.98	recirc.	-	5.56	recirc.	-
Effluent Susp. Solids conc. - ppm							
(i) Simple average		54.0	61.5	59.0	26.9	25.8	15.7
(ii) Weighted average		54.0	62.6	59.5	27.1	25.8	16.1
Total Alum added - pounds		1970	recirc.	0	1091	recirc.	0
Total Susp. Solids in effluent - pounds		9657	11202	10639	4466	4239	2649
Improved removal pounds SS		1082	-563	0	-1819	-1590	0

Table 2 indicates that 879 pounds (from 5 ppm to 11 ppm) of additional alum feed resulted in a reduced discharge of suspended solids from Clarifier #1 and #2 during the November 9 to December 10, 1965, period. Clarifier #1 discharged 2901 pounds fewer suspended solids than expected without the increased alum feed. Approximately 1027 pounds of this improvement may be due to alum recirculated back to the aeration tanks in the activated sludge as demonstrated with Clarifier #2. Again inherent in the test data is the observation that Clarifier #3 would out perform Clarifiers #1 and #2 in the absence of alum additions.

As with BOD application of higher alum dosages (up to 73 ppm) did not show corresponding effluent improvement for suspended solids beyond that demonstrated for the lower 11 ppm trials - at least for the short periods of application tested.

(c) The Effect on Effluent Turbidities

Effluent turbidity was affected by alum addition showing a trend that followed the suspended solids removals.

In parallel with the effects noted for BOD and suspended solids, effluent turbidity increased in both Clarifiers #1 and #2 when the alum solution was fed directly into Clarifier #1 rather than into the preceding aeration tank. The effect is shown in the results for this period from October 27 to November 8, 1965. Turbidities of 65, 75 and 36 Jackson Candle Units (JU) were averaged for Clarifiers #1, #2 and #3 respectively during this time.

In contrast, the 11 ppm alum added to the aeration tank preceding Clarifier #1 achieved a modest advantage in effluent turbidities for the period November 9 to December 10, 1965. Effluents from Clarifiers #1, #2 and #3 then averaged 34, 41 and 42 JU respectively. However, at an average feed of 5.5 ppm alum addition maintained during the period February 7 to March 5, 1966, the alum addition appeared insufficient to provide better effluent from the treated clarifiers. Clarifier effluents during the later period averaged 17, 18 and 12 units respectively for the three clarifiers. The data throughout indicated that Clarifier #3 would maintain the better effluent with respect to turbidities in the absence of any alum addition. About 85% of the 43% improvement in the turbidity of Clarifier #1 receiving 11 ppm alum occurred with Clarifier #2.

(d) The Effect on Effluent Phosphate

Phosphate removals due to the low level alum addition were less than 11%. No distinction between alum addition directly to the clarifier or to the aeration tank preceding the clarifier could be discerned as was obvious with BOD, suspended solids and turbidity. Comparison of the period November 9 to December 10, 1965 and the period February 7 to March 5, 1965 showed a very modest advantage to Clarifier #1 when sufficient alum was added (see Table 3).

TABLE 3

ALUM ADDITION EFFECT ON PHOSPHATE

	Clarifiers		
November 9 to December 10, 1965	1	2	3
Alum added (11 ppm) - pounds	1970	recirc.	0
Phosphate in effluent - pounds as PO_4	3412	3741	3761
Improved Retention - pounds PO_4	349	20	0
February 7 to March 5, 1965			
Alum added (5.5 ppm) - pounds	1091	recirc.	0
Phosphate in effluent - pounds as PO_4	2822	2701	2751
Improved Retention - pounds PO_4	-71	50	0

Table 3 indicates some 420 pounds of phosphate were retained (from -71 to 379 lb) by increasing the alum from 1091 to 1970 lbs. The removal of phosphate appeared to be largely confined to Clarifier #1 actually receiving the influence of fresh alum.

Higher alum dosage improved phosphate removal factors. All instances of alum addition approaching or exceeding 20 ppm were associated with periods of improved phosphate removal in Clarifier #1.

Analysis of data to correlate the erratic phosphate concentration observations with the amount of aluminum held in the return sludge solids showed no clearly discernable relationship.

(e) The Effect on Effluent Alkalinity

Although alum is an acidic material with a tendency to release sulphuric acid on hydrolysis, no reductions in effluent alkalinity were observed to correlate with the addition of alum solution to the sewage treatment process. Even the 73 ppm alum added on February 4 and the 68 ppm added on January 9 did not influence effluent alkalinity. The treated effluent from Clarifier #1 in fact shifted upwards

in alkalinity on these occasions. All alkalinity averages concurred within 2½% of one another in all the examined test periods.

Of the 16 comparisons made on return sludge samples (not a routine test), no significant variations in average sludge alkalinity could be found. The alum influenced sludge averaged a slightly higher alkalinity - (594 ppm versus 584 ppm).

(f) The Effect on Kjeldahl Nitrogen

Kjeldahl nitrogen appeared completely uninfluenced by the alum addition. Matching all the significant periods of comparison, a slight but constant removal advantage was determined to obtain in Clarifier #3 and Clarifier #2 in that order. The Kjeldahl nitrogen followed the expected BOD removal trends that would be anticipated in the absence of alum additions to Clarifier #1. Effluents averaged 27.3, 26.8 and 26.2 ppm for Clarifiers #1, #2 and #3 respectively over the total period of sampling.

CONCLUSIONS

1. The addition of alum into the aeration tank preceding secondary clarifier treatment was beneficial. In the average range of 5½ to 11 ppm alum (as alunogenite), one pound of alum appeared to remove approximately:

0.92 pounds of BOD

0.97 pounds of suspended solids

0.213 pounds of phosphate

43% of the average turbidity

Assuming a cost of $70.00 per ton of alum, the removal of additional BOD through the use of alum would cost 3.5¢ per pound of BOD removed (chemical cost only). At a dosage of 11 ppm alum the increase in treatment cost would be $3.90 per million gallons.

An effluent BOD ranging between 16 and 40 ppm was reduced by 36%. A suspended solids concentration ranging between 27 and 96 ppm was reduced by 46%. Phosphate removal was limited to an overall 11%.

2. The addition of alum directly to a sewage treatment plant clarifier without additional chemicals, such

as lime, resulted in increased sludge volume and decreased effluent quality.

3. The change in effluent alkalinity was too minute to be demonstrated.

4. The removal of suspended solids, BOD and turbidity was related to improved sludge settling.

5. Phosphate removal appeared to be a matter of chemical precipitation by the aluminum ion.

6. The process may have a relatively limited range of application as alum dosages much exceeding 11 ppm did not exhibit correspondingly effective results.

RECOMMENDATIONS

The addition of alum to the aeration of a section of an activated sludge type sewage treatment process is recommended as a method of providing improved removal of BOD and suspended solids, particularly in the case of overloaded plants.

Alum addition directly to secondary clarifiers is not recommended as sludge bulking may result.

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